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JOSEPH A. HOLMES, DIRECTOR

# INVESTIGATIONS OF FUSE AND MINERS' SQUIBS

BY

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# INVESTIGATIONS OF FUSE AND MINERS' SQUIBS.

By Clarence Hall and Spencer P. Howell.

## INTRODUCTORY STATEMENT.

This paper is one of a series of publications dealing with blasting supplies for use in mines, tunnels, and quarries that is being issued by the Bureau of Mines. The tests herein reported, which were conducted by A. J. Hazlewood at the Pittsburgh station of the bureau, and the conclusions drawn therefrom point out the relative safety and efficiency of different kinds of fuse and miners' squibs. The purpose of this paper is to enable those in charge of blasting work to select to better advantage such devices for igniting explosives and thus aid in reducing accidents caused by misuse.

As the efficiency of fuse and miners' squibs bears a direct relation to the relative safety of these devices, this paper would be incomplete if it did not consider this phase of the subject. Clearly, a fuse or squib that does not surely and adequately do the work for which it is intended is a menace to the user.

## DEVICES USED TO IGNITE OR DETONATE EXPLOSIVES.

Charges of explosives are fired by means of various devices. The particular device to be employed depends upon the kind of explosive to be fired and the conditions under which it is used. Dynamites, permissible explosives, and other detonating explosives are usually fired by means of detonators, which are themselves ignited by means of a fuse or by an electric current. When a detonator is fitted with a means of firing it by an electric current it is called an electric detonator.

Black blasting powder is ignited by means of electric igniters, fuse or miners' squibs. An electric igniter consists of a short tube of spirally wrapped paper, into which is fitted a metallic bridge, a composition like that on a match, a sulphur plug, and a pair of insulated wires, the whole so arranged that the composition may be fired by means of an electric current.

As electric igniters and electric detonators are embedded in the explosive to be fired and are isolated by means of the stemming (the material tamped on the charge) they are the safest means of igniting charges of explosives in fiery mines. The safety and efficiency of electric detonators will be treated in another paper.



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## FUSE.

Fuse was formerly called "safety fuse," and the practice still obtains, though the word safety has come to mean something far beyond what it was intended to mean when originally applied to fuse.

Fuse, as now known, was invented in 1831 by William Bickford, of Cornwall, England. Before its invention straws containing finely granulated gunpowder were used for igniting charges of blasting powder. Metallic needles, similar to those still employed in some of the coal mines of this country, were used to make an opening through the stemming from the charge to the mouth of the drill hole. The straws containing the gunpowder were pushed into the opening and formed a powder train for igniting the charge. As the rate of burning in this train of powder was fast and irregular, sometimes approaching an explosion, the use of a slow-burning paper to communicate the flame to the powder train was found necessary. The interval that elapsed between the application of the flame to the paper and the ignition of the powder train gave the miner more time to retreat to a place of safety. Sometimes, however, he was not successful and the irregular burning of the powder train and paper exposed the miner to considerable risk. So, when fuse was placed on the market and its comparative safety and efficiency for firing charges of blasting powder became known it was favorably received. Since then the use of fuse has steadily increased and now hundreds of thousands of feet of fuse are used daily in this country for firing blasts of explosives.

"Safety" fuse is defined by the British explosives act of 1875 as follows: "The term 'safety fuse' means a fuse for blasting which burns and does not explode, which does not contain its own means of ignition, and which is of such strength and construction and contains an explosive in such quantity that the burning of such fuse will not communicate laterally with other fuse." The name "safety" was applied to this kind of fuse because the fuse, when used under actual working conditions, burned at a uniform rate and did not explode. The inventor did not claim, nor has it been generally accepted, that ordinary fuse can be used with safety in gaseous coal mines.

## SQUIBS.

It was long ago observed that straws containing fine grains of gunpowder would ignite charges of blasting powder, even though the straws and their core of powder were not continuous from the charge to the mouth of the drill hole, because of the propelling force of the burning powder. The first miners' squibs consisted of such relatively short lengths of powder-filled straws. One of these when ignited would dart from the mouth of a drill hole to the charge of explosive

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through the opening previously made with the needle, and would ignite the charge when the core of powder had burned through. With such squibs, as with the early forms of fuse, the time that elapsed between the lighting of the squib and the explosion of the charge of powder was very short, hence a slow-burning paper taper was added to the squib to increase the interval. Modern miners' squibs have been perfected after this fashion. Each squib consists of a small paper tube about 4 inches long filled with a powder core, and has at one end a slow-burning paper taper or match.

## FUSE.

### CLASSES.

The moisture conditions under which blasting is done vary widely, ranging from the blasting of very dry material to submarine work. Hence it is advisable to manufacture fuse adapted to these various conditions, and in this country fuse is made in five classes as follows:

1. Fuse for use in dry material.
2. Fuse for use in damp material.
3. Fuse for use in wet material.
4. Fuse for use in very wet material.
5. Fuse for use in submarine work.

Class 1 is cheaply constructed, has no waterproof qualities, and requires great care in manipulation. Its use is small, and it is not considered reliable.

Class 2 is better than class 1, but has not all the requirements of a good fuse. It will stand immersion under a few inches of water for a few minutes, but it is not recommended for general use. This class, as well as class 1, is invariably subject to lateral sparking when burning.

Classes 3, 4, and 5 are well made. They will stand immersion in shallow water 30 minutes, 24 hours, and 96 hours, respectively. In burning they show little, if any, lateral sparking or glowing. They usually burn quietly and steadily and will not burst nor explode. In metalliferous mines, where it is often necessary to use different lengths of fuse at the same time in order to fire dependent shots, the projecting ends of the different lengths, if the fuse is of these grades, can be coiled and placed in the mouth of a drill hole to keep them from being cut by flying fragments of rock. The lateral sparking is rarely sufficient to ignite adjacent fuse or cause short-circuiting, and accordingly the practice can be followed with comparative safety.

During the manufacture of fuse such defects as local irregularities in thickness, which indicate that the powder train is not uniform or not continuous, are detected by mechanical means. In recent years X-ray devices have been used to detect gaps and other irregularities in the powder train.

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## RATE OF BURNING.

In England the required rate of burning of fuse is about 90 seconds per yard, and regulations governing the regularity and uniformity of burning are enforced.

The commission appointed by the French ministry of public works[a] to investigate the fuse used in mining operations in France reported that the average rate of burning of fuse made in France was about the same as that of samples of fuse obtained from other European countries. The method of manufacturing fuse was stated to be much the same in all factories, and, although the composition of the exterior envelope varied considerably, its composition seemed to have little effect on the rate of burning. The rate of burning, according to the committee, varied with the composition, degree of fineness, and the hygrometric condition of the powder train.[b] The age of the fuse, the conditions under which it had been stored, the manner in which it was used, and especially the way it was tamped in a drill hole, all had a marked effect. It was found that the rate of burning of fuse stored in a very damp place varied 17 to 45 per cent; warming the fuse near a stove gave a variation of 30 per cent; and under actual working conditions in rock the rate of burning varied 22 to 82 per cent, being governed by the method of tamping and the kind of stemming used.

The rates of burning of the various kinds of fuse sold in this country vary from 18 to 40 seconds per foot in open air. However, the miner or shot firer seldom knows the rate of burning of the different kinds of fuse. It is true that some fuse is marked slow or fast burning and is even distinguished by the color of the paper wrapper, but this is not always the case. Without such information a miner who is accustomed to a certain brand of fuse may use another that burns faster with the result that a charge may explode prematurely and menace all connected with the work. However, it is believed that the rate approved by the Bureau of Mines—namely, 90 seconds per yard—will meet the various mining conditions in this country.

## SAMPLES TESTED.

Six samples of fuse, all belonging to classes 3 and 4, in which the weight of powder per foot varied from 1.42 to 0.37 grams, were selected for tests to determine the effect of this particular variation on their relative safety and reliability. The other characteristics of the samples that might affect their relative safety and reliability were practically uniform. Some of these characteristics, such as the size and composition of the powder, and the rigidity and impermeability of the coverings, showed little variation in the samples tested and can, therefore, be disregarded in so far as they apply to the results reported in this paper.

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[a] Annales des Mines, ser. 10, vol. 11, 1907, p. 255–260.

[b] For a discussion of the rate of burning of fuse see Technical Paper 6, Bureau of Mines.

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For convenience of description the different concentric coverings of the powder core, beginning with the innermost, are designated as follows:

1. Inner covering.
2. Inner-middle covering.
3. Middle covering.
4. Middle-outer covering.
5. Outer covering.

In a fuse that has only four coverings the inner-middle covering has been omitted; in a fuse that has only three coverings the inner-middle covering and the middle-outer covering have been omitted.

SAMPLE A.

In this sample the core consists of a powder train and 1 red cotton thread; the inner covering consists of 10 hemp threads; the middle covering consists of 5 cotton threads impregnated with an asphaltic composition; the middle-outer covering consists of paper; and the outer covering consists of 10 cotton threads coated with a white clay composition.

SAMPLE B.

The core consists of a powder train and 1 white cotton thread; the inner covering consists of 10 hemp threads; the inner-middle covering consists of 5 fine cotton threads impregnated with an asphaltic composition; the middle covering and the middle-outer covering each consist of a $\frac{5}{8}$-inch cotton tape impregnated with an asphaltic composition, and the outer covering consists of a $\frac{5}{8}$-inch cotton tape covered with whiting. Each covering of tape is wrapped in reverse order.

SAMPLE C.

The core consists of the powder train and 1 white cotton thread; the inner covering consists of 10 hemp threads; the middle covering consists of 6 cotton threads impregnated with a gutta-percha composition; the middle-outer covering consists of 1 cotton tape $\frac{5}{8}$ inch wide; and the outer covering consists of 10 cotton threads coated with a white clay composition.

SAMPLE D.

The core consists of the powder train and 1 red cotton thread; the inner covering consists of 10 hemp threads; the middle covering consists of 5 cotton threads impregnated with an asphaltic composition; the middle-outer covering consists of paper; and the outer covering consists of 10 cotton threads coated with a white clay composition.

SAMPLE E.

The core consists of the powder train and 1 cotton thread; the inner covering consists of 10 cotton threads impregnated with sodium silicate; the middle covering consists of 5 cotton threads impregnated

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with an asphaltic composition; and the outer covering consists of 10 cotton threads covered with a white clay composition.

### SAMPLE F.

The core consists of the powder train and 1 cotton thread; the inner covering consists of 12 fine cotton threads impregnated with sodium silicate; the middle covering consists of 9 cotton threads impregnated with an asphaltic composition; the middle-outer covering consists of 5 cotton threads; and the outer covering consists of 10 cotton threads covered with a white clay composition.

## QUANTITY OF POWDER PER FOOT IN FUSE.

A definite length of each sample of fuse was selected; it was cut lengthwise and the powder was carefully shaken out and weighed.

The following tabulation shows the number of feet of fuse taken, the total weight of powder obtained, and the weight per foot of the powder in each sample:

*Weight of powder in different samples of fuse.*

| Designation of sample. | Length of sample. | Weight of powder core. | Weight of powder per foot of fuse. |
|---|---|---|---|
| | *Feet.* | *Grams.* | *Grams.* |
| A | 18 | 25.50 | 1.42 |
| B | 20 | 22.60 | 1.13 |
| C | 25 | 27.07 | 1.08 |
| D | 26 | 27.66 | 1.06 |
| E | 45 | 28.50 | .63 |
| F | 45 | 16.53 | .37 |

## SIZE OF POWDER GRAINS.

The powder obtained from the core of each of the various samples of fuse was run through screens of the following sizes: Forty mesh, 60 mesh, 80 mesh, 100 mesh, and 150 mesh. The weights of the different sizes of powder separated are shown in the accompanying table.

*Size of powder grains in fuse.*

| Designation of sample. | A. | B. | C. | D. | E. | F. |
|---|---|---|---|---|---|---|
| Weight of powder.....grams.. | 25.50 | 22.60 | 27.07 | 27.66 | 28.50 | 16.53 |
| Grams of powder caught on 40 mesh.. | 0.00 | 0.78 | 00.00 | 00.00 | 00.00 | 00.00 |
| Grams of powder caught on 60 mesh.. | 5.41 | 8.37 | 11.82 | 3.45 | 10.55 | 6.55 |
| Grams of powder caught on 80 mesh.. | 5.82 | 4.67 | 5.32 | 12.94 | 5.82 | 3.55 |
| Grams of powder caught on 100 mesh.. | 5.51 | 3.01 | 3.87 | 3.33 | 3.27 | 2.24 |
| Grams of powder caught on 150 mesh.. | 4.65 | 3.40 | 3.25 | 2.39 | 2.54 | 1.61 |
| Grams of powder through 150 mesh.. | 3.41 | 2.05 | 2.55 | 4.73 | 5.98 | 2.24 |
| Total grams of powder caught..... | 24.80 | 22.28 | 26.81 | 26.84 | 28.16 | 16.19 |
| Percentage of powder caught on 40 mesh.. | 00 | 4 | 00 | 00 | 00 | 00 |
| Percentage of powder caught on 60 mesh.. | 22 | 37 | 44 | 13 | 37 | 40 |
| Percentage of powder caught on 80 mesh.. | 23 | 21 | 20 | 48 | 21 | 22 |
| Percentage of powder caught on 100 mesh.. | 22 | 14 | 14 | 12 | 12 | 14 |
| Percentage of powder caught on 150 mesh.. | 19 | 15 | 12 | 9 | 9 | 10 |
| Percentage of powder through 150 mesh.. | 14 | 9 | 10 | 18 | 21 | 14 |
| | 100 | 100 | 100 | 100 | 100 | 100 |

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## COMPOSITION OF POWDER.

Analyses of the powder from the core of each of the different samples of fuse tested gave the following results:

*Analyses of powder from fuse.*

| Designation of sample. | Composition of powder. | | | | Analyst. |
|---|---|---|---|---|---|
| | Moisture. | Potassium nitrate. | Sulphur. | Charcoal. | |
| A | 0.40 | 79.96 | 9.78 | 9.86 | W. C. Cope. |
| B | .42 | 74.61 | 8.68 | 16.29 | J. H. Hunter. |
| C | .50 | 71.82 | 10.09 | 17.59 | W. C. Cope. |
| D | .55 | 66.60 | 13.48 | 19.37 | Do. |
| E | .40 | 67.07 | 13.65 | 18.88 | Do. |
| F | .50 | 66.69 | 13.27 | 19.54 | Do. |

## GASEOUS PRODUCTS OF COMBUSTION.

Two samples of fuse, each 100 feet long, were subjected to tests to determine the composition of the gaseous products of combustion. Each sample was burned in a Bichel pressure gage having a capacity of 15 liters; the air in the gage was at atmospheric pressure at the beginning of the test. The ends of the fuse were passed through a small opening in the gage, ignited, and pushed into the gage; the opening was immediately closed. In this way the pressure of the gases within the gage at room temperature was obtained; the volume of the gases within the gage at a temperature of 0° C. and a pressure of 760 mm. was computed.

Fuse C was an ordinary fuse; fuse E was an improved fuse. The results of the tests follow:

*Gaseous products of combustion of fuse.*

| Designation of fuse. | C. | E. |
|---|---|---|
| Length of sample.....feet.. | 100 | 100 |
| Weight of sample.....grams.. | 674 | 667 |
| Weight of powder in sample.....do.... | 108 | 63 |
| Pressure within 15-liter gage at gage temperature.....kilograms per square centimeter.. | 6.6 | 1.8 |
| Temperature of gage.....°C.. | 19 | 27 |
| Volume of gas at 0° C. and 760 mm. pressure.....liters.. | 103.1 | 37.1 |
| Gaseous products of combustion, percentage by volume: [a] | | |
| Carbon dioxide ($CO_2$) | 32.7 | 25.0 |
| Oxygen ($O_2$) | 1.4 | 5.7 |
| Carbon monoxide (CO) | 23.4 | 13.9 |
| Hydrogen ($H_2$) | 13.8 | 9.9 |
| Methane ($CH_4$) and other hydrocarbons | 4.1 | 5.9 |
| Nitrogen ($N_2$) | 23.8 | 39.0 |
| Hydrogen sulphide ($H_2S$) | 0.8 | 0.6 |
| | 100.0 | 100.0 |

[a] A. L. Hyde, analyst.



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The quantity of smoke from sample E was considerably less than that from sample C, and fuse C was badly charred. The remarkable difference in the volume of gas produced by each of the two samples is explained partly by the difference in the weight of powder, sample C containing 108 grams and sample E 63 grams of powder; but a much more important reason is the covering. In the improved fuse (sample E) the threads are impregnated with an incombustible material—silicate of soda—hence the spinning threads adjacent to the powder train do not burn as do those of the ordinary fuse (sample C) and accordingly the volume of the gases produced is less.

A comparison of the analyses of the gaseous products of combustion shows how much better the improved fuse is than the ordinary fuse. The decreased percentages of hydrogen sulphide ($H_2S$) and especially of carbon monoxide (CO) from the improved fuse are of particular significance, in view of the fact that the same lengths of fuse were used in the two tests and that the gaseous products of combustion were diluted by the same quantity of air (15 liters) at atmospheric pressure. The results indicate that when fuse is used for firing charges of explosives under the conditions that prevail in many metalliferous mines in this country proper ventilation should be provided, as the gases evolved from the burning of large quantities of fuse, particularly ordinary fuse like sample C, would no doubt affect the health of the miners.

## TESTS OF EFFICIENCY OF SPIT.

When the powder core of a fuse or miner's squib is ignited, the pressure produced by the burning powder because of partial confinement causes the incandescent particles and products of combustion of the powder to be projected out of the end of the fuse or miner's squib. This phenomenon is called spitting.

Preliminary tests were made with an apparatus to determine the maximum distance at which the spit of a fuse would ignite a similar fuse when placed in line with and in front of it. The apparatus consisted of two tubes, one stationary and one sliding, within which the two pieces of fuse, with square-cut ends, were snugly fitted. For each sample of fuse a length of air gap was established, without previous failure to obtain ignition, at which ignition was obtained in each of three trials and beyond which it was impossible to establish the distance.

This method of testing was not satisfactory for the reason that the direction of the spit was not always such that the matter ejected was driven directly toward the powder train of the second fuse. To require that a fuse spit directly out and in line with the powder train is unnecessary for this requirement in no way makes the fuse more reliable when used either with a detonator or with black blasting

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powder. The tests indicate the relative effectiveness, under the conditions outlined, of the various samples tested.

*Test of spitting of fuse.*

| Name of sample. | Distance between ends of fuse. | Result. |
|---|---|---|
| | *Inches.* | |
| A [a] | 1 | Ignition. |
| | 2 | Do. |
| | 3 | Do. |
| | 3 | No ignition. |
| | 2½ | Do. |
| | 2¼ | Do. |
| | 2¼ | Do. |
| | 2 | Ignition. |
| | 2 | Do. |
| | Maximum distance established at 2 inches. | |
| B [b] | 2 | Do. |
| | 2¼ | Do. |
| | 2¼ | No ignition. |
| | 2 | Ignition. |
| | 2 | No ignition. |
| | 1⅞ | Ignition. |
| | 1⅞ | Do. |
| | 1⅞ | Do. |
| | Maximum distance established at 1¾ inches. | |
| C [c] | 1½ | No ignition. |
| | 1 | Ignition. |
| | 1¼ | Do. |
| | 1¼ | Do. |
| | 1¼ | Do. |
| | Maximum distance established at 1¼ inches. | |
| D [d] | 1 | Do. |
| | 1½ | Do. |
| | 2 | No ignition. |
| | 1½ | Do. |
| | 1 | Do. |
| | ⅞ | Do. |
| | ¾ | Ignition. |
| | ¾ | Do. |
| | ¾ | Do. |
| | Maximum distance established at ¾ inch. | |
| E [e] | 1½ | No ignition. |
| | 1⅛ | Ignition. |
| | 1¼ | No ignition. |
| | 1 | Ignition. |
| | 1 | Do. |
| | 1 | Do. |
| | Maximum distance established at 1 inch. | |
| F [f] | 1 | No ignition. |
| | ⅞ | Do. |
| | ¾ | Do. |
| | ¾ | Ignition. |
| | ⅝ | Do. |
| | ⅝ | Do. |
| | Maximum distance established at ⅝ inch. | |

[a] Weight of powder per foot, 1.42 grams.
[b] Weight of powder per foot, 1.13 grams.
[c] Weight of powder per foot, 1.08 grams.
[d] Weight of powder per foot, 1.06 grams.
[e] Weight of powder per foot, 0.63 gram.
[f] Weight of powder per foot, 0.37 gram.

A variation of the method of testing the spit of a fuse was to place the two pieces of fuse the desired distance apart in a glass tube whose inside diameter was the same as the outside diameter of the fuse.

Samples A, C, E, and F were thus tested. The results are given below.

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*Test of spitting of fuse inside glass tube.*

| Designation of sample. | Distance between ends of fuse. | Result. |
|---|---|---|
| | *Inches.* | |
| A..... | 4 | Ignition. |
| | 5 | Do. |
| | 6 | Do. |
| | 7 | Do. |
| | 8 | No ignition. |
| | 7½ | Do. |
| | 7¼ | Do. |
| | 7 | Do. |
| | 6¾ | Do. |
| | 6½ | Ignition. |
| | 6½ | Do. |
| | 6½ | No ignition. |
| | 6¼ | Ignition. |
| | 6¼ | No ignition. |
| | 6 | Ignition. |
| | 6 | Do. |
| | Maximum distance established at 6 inches. | |
| C..... | 4½ | Do. |
| | 5½ | No ignition. |
| | 5 | Ignition. |
| | 5¼ | No ignition. |
| | 5 | Ignition. |
| | 5 | Do. |
| | Maximum distance established at 5 inches. | |
| E..... | 3 | No ignition. |
| | 2½ | Do. |
| | 1½ | Ignition. |
| | 2 | No ignition. |
| | 1¾ | Ignition. |
| | 1¾ | Do. |
| | 1¾ | Do. |
| | Maximum distance established at 1¾ inches. | |
| F..... | ½ | No ignition. |
| | ⅜ | Do. |
| | ⅜ | Do. |
| | ¼ | Do. |
| | ¼ | Ignition. |
| | ⅛ | Do. |
| | ⅛ | Do. |
| | Maximum distance established at ¼ inch. | |

A small number of tests were made with sample F (spit one-eighth of an inch) to determine whether it would ignite a detonator when the space between the composition of the detonator and the fuse was four-fifths of an inch, the fuse being crimped just within the detonator by means of a cap crimper. Twenty-five trials resulted in an ignition each time.

This fuse was also tested by embedding it in size C black blasting powder. Twenty-five trials resulted in an ignition in 17 cases and no ignition in 8 cases. Sample E was similarly tested, with the result that ignition was obtained in each of 25 trials. These tests show that the spit of sample F, namely, one-eighth inch, is not sufficient to always ignite charges of black blasting powder; hence, a fuse containing such a small quantity of powder per foot as 0.37 gram is unreliable; but a fuse containing 0.63 gram of powder per foot, such as sample E, whose spit is 1¾ inches, shows favorable results as to reliability and safety when used in gas mixtures.

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## TESTS IN INFLAMMABLE GAS MIXTURES.

The different samples of fuse were tested in inflammable mixtures of gas and air in gallery No. 3.

Gallery No. 3 consists essentially of a steel box measuring 18 inches by 18 inches by 24 inches, having in front two plate-glass observation windows. One end of this box is closed by means of a square diaphragm of paraffined paper. A fan connected to the gallery by two pipes entering at opposite sides is used to insure thorough mixing of the gas and air. This mixing is known to be thorough for the reason that frequent samples taken simultaneously from different parts of the gallery have been analyzed and found to be of the same composition.

The bell of the gasometer is calibrated in order to obtain various percentages of gas in the gallery. In the tests herein reported the gas and air mixture contained 8 to 8.5 per cent of methane and ethane. This mixture is very close to the most explosive mixture of natural gas and air; and as the sensitiveness of the mixture varies only slightly when the percentage of methane and ethane is between 8 and 8.5 per cent, the various trials were made under comparable conditions. Compressed air was used to clean out the gallery previous to tests in every new mixture.

In the trials a piece of fuse 5 to 6 inches long was inserted into the gallery through a small hole in the paper diaphragm so that the fuse could be ignited safely and easily from without and was allowed to spit directly into the gas-air mixture. Frequently the same mixture was used for two or three trials, but in no case were trials made simultaneously.

The following tabulation shows the number of trials made with each sample, the number of ignitions of each sample, the percentage of ignitions, and the weight of powder per foot:

*Trials of fuse in inflammable gas mixtures.*

| Designation of sample. | Number of trials. | Number of ignitions. | Percentage of ignitions. | Weight of powder per foot (grams). |
|---|---|---|---|---|
| A | 102 | 44 | 43 | 1.42 |
| B | 109 | 30 | 28 | 1.13 |
| C | 271 | 30 | 11 | 1.08 |
| D | 76 | 2 | 2.6 | 1.06 |
| E | 100 | 0 | 0 | .63 |
| F | 100 | 0 | 0 | .37 |

## PRACTICAL CONCLUSIONS.

The foregoing tests of fuse in inflammable gas mixtures show that when the quantity of powder per foot in a fuse is reduced, other conditions being constant, or nearly so, the relative safety from ignition of gas by the fuse increases. However, other conditions than those

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indicated in these tests are requisite before a fuse can be considered permissible for use in a coal mine that generates inflammable gases. These conditions are:

1. Good mechanical construction with regard to safety.
2. Safe and reliable methods of igniting the fuse.
3. A reliable fuse.

Taking up in detail each of the above-mentioned conditions, the facts regarding each may be stated as follows:

1. A fuse of good mechanical construction must conform to the following conditions:

(*a*) A continuous uniform powder core. Any enlargement of the powder core that might cause side spitting would not be good mechanical construction; neither would a fuse having breaks in the powder core be considered of good mechanical construction.

(*b*) A proper and sufficient ratio between the pressure required to burst the envelope of the fuse and the pressure produced within it by the burning powder train. This ratio may be considered a factor of safety and should be large enough to always prevent the side spitting so common in fuse of classes 1 and 2.

(*c*) A pliable waterproof envelope. Pliability is essential in order that the conditions under (*b*) may always prevail. Freedom from moisture should exist in order that misfires may not occur.

2. As fuse does not contain its own means of ignition, safety and reliability of fuse ignition involves a discussion of the fuse igniter. Clearly any fuse igniter that when properly attached to a fuse ignites gas should be condemned, as well as any fuse igniter that fails to ignite the fuse with certainty. No great difficulty should be encountered in perfecting a safe and reliable fuse igniter, judging from the results obtained from samples of fuse igniters submitted to this bureau for test.

One of these fuse igniters fits on a fuse in the same manner as a detonator. One end of the igniter is closed, and the composition within it is ignited when pinched by a special crimper. This crimper is so made that it surrounds the inclosed end of the fuse igniter. The tests of this fuse igniter were made in gallery No. 3 in the same manner as tests with fuse. A part of the crimper and the fuse igniter were placed in the gas mixture. The sample of fuse used was of such a length that the time interval between the ignition of the fuse igniter and the spitting of the open end of the fuse was adequate for determining that the ignition was not caused by the spit of the free end of the fuse. Out of 17 trials 1 ignition occurred. This ignition took place on pinching the fuse igniter, and was due to the flame projected from the igniter. The fuse igniter was tested for reliability by crimping it on a piece of fuse and attempting to ignite the fuse by its use. In 46 trials the fuse igniter failed 5 times to ignite the fuse, and therefore this fuse igniter can not be considered reliable.

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Another fuse igniter, which operates on the principle of an inclosed friction "safety" match, was tested informally, and a small number of tests showed no unfavorable results as regards either safety or reliability.

3. A reliable fuse should have a uniform rate of burning, and its spit should not fail to ignite the explosive or detonator with which the fuse is used.

It should not be concluded, however, that any fuse having the proper envelope and proper weight of powder per foot will necessarily pass the requirements, regardless of the composition of the powder or of its fineness; nor should the use of any fuse, even when a safe and reliable method is provided for its ignition, be assumed to be safe in a body of inflammable gas.

## GOVERNMENT SPECIFICATIONS FOR PURCHASE.

The salient features of the recent specifications adopted by the United States Government for the purchase of all fuse for use on the Canal Zone and on the different projects of the Reclamation Service are as follows:

All fuse furnished shall be of the type known as "safety fuse," shall be free from defects, and shall be capable of being stored for at least six months without deterioration. It shall be put up in properly labeled packages containing two coils each, and the rate of burning in open air (viz, 90 seconds per yard) shall be stated on each wrapper. Sixty package lots, containing 120 50-foot coils, shall be packed in air-tight wooden cases. At least 118 coils in each case shall be in continuous lengths of 50 feet; the 2 remaining coils may be made up of two pieces each. The ends of the two coils last mentioned must be tied together. All safety fuse when burning shall not burst nor explode in any part of its length. It shall burn without any such lateral sparking or glowing at the sides as might cause short-circuiting when the fuse is coiled on itself. When burned in the open air it shall burn quietly and uniformly, the rate of burning not varying more than 10 per cent over or under the stated rate (90 seconds per yard). The powder core shall be continuous, without gaps, and of sufficient quantity so that the final spit is strong enough to ignite another piece of fuse when the ends of two pieces are separated at least 1 inch. All safety fuse shall be sufficiently waterproof to stand immersion for not less than 30 minutes in water at least 1 foot in depth. One 50-foot length will be selected at random from each case for the purpose of inspection.

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### TRANSPORTATION AND STORAGE.

"Safety fuse" when transported on railroads is regarded in this country, as well as in foreign countries, as ordinary freight. A carload lot of fuse may contain hundreds of pounds of gunpowder, but as the core of powder is imprisoned between layers of hemp and cotton cord it is deprived of its effective explosive force. Fuse should be stored in a dry place of moderate temperature, and not in an iron box exposed to the direct rays of the sun or to other sources of heat. The plan of using up an old lot of fuse before opening a new one will insure the best results.

### PRECAUTIONS TO BE TAKEN IN USE.

Careful tests should be made of the rate of burning of fuse whenever there is any doubt as to its soundness. The manufacturers may produce a fuse with a regular rate of burning, but the rate may be changed by bad handling—for instance, by squeezing the fuse so as to disturb the powder train, or by suddenly and roughly opening the coil when it is stiff from cold so as to crack the fuse—or the fuse may be bruised by rubbing against the rough surfaces of rock.

Fuse should be carefully handled and never laid in a damp place before using. In cutting the fuse and in fitting it into place, care must be taken that the powder core does not run out of the fuse, for that might cause a misfire. The fuse should be cut straight across with a sharp knife just before placing the end in the detonator. In a humid atmosphere at least 1 inch should be cut off the fuse before insertion in the detonator. The fuse should be fitted gently into the detonator and then the detonator should be crimped on the fuse by the proper crimper.

The best method of inserting the detonator and attached fuse into a stick of explosive or primer is to open the top of the cartridge by unfolding the paper at the end, and to make with a wooden skewer a hole in the top of the cartridge, deep enough to allow the detonator to be pushed into the cartridge up to the line of crimping. The end of the paper envelope should then be gathered about the fuse, and the whole bound with twine so as to fasten the detonator and fuse properly in place. Extreme care should be taken that the fuse and detonator do not come apart, because if there is any space between the detonator and the fuse the explosion may be prevented altogether or may be a very poor one. In addition, care should be taken that the detonator is not completely buried in the explosive, for if lateral sparking from the fuse occurs it may set fire to the explosive before the detonator is set off. This lateral sparking has been the common cause of inferior and dangerous explosions.

With all the care exercised by the manufacturers of "safety fuse" to perfect the quality of fuse, human life depends in a great measure

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on the proper use of fuse by the miner himself. He should have a better understanding than he usually has of the action of fuse, because, under certain conditions, there is always an inherent risk in its use.

## MINERS' SQUIBS.

Miners' squibs are used to ignite black blasting powder. The method of using them has been previously described. There are two kinds of these squibs in general use: One, designated herein as sample G, commonly known as a gas squib; the other, designated as sample H, commonly known as a sulphur squib. They are similar in many respects. Each consists of a train of finely grained black powder wrapped tightly with thin tough paper that encircles the powder about five times. A part of this wrapper is twisted in the form of a taper beyond the powder train to a distance of about $2\frac{1}{2}$ inches. The powder core is about 4 inches long and slightly less than one-eighth inch in diameter. The weight of the powder in each squib is about 0.4 grams. The total weight of a squib varies from 0.6 to 0.7 grams, a sulphur squib being somewhat heavier than a gas squib.

The slow-burning paper taper or match of sample G is impregnated with a composition that does not flame in burning but glows throughout its length. The match of sample H is dipped in sulphur and when ignited burns with a flame and at a somewhat faster rate than the match of sample G.

The results of the physical examination of these two samples may be tabulated as follows:

*Dimensions and weights of squibs.*

| Designation of sample. | G. | H. |
|---|---|---|
| Length of squib proper and match.....inches.. | $6\frac{2}{16}$ | $6\frac{7}{16}$ |
| Length of squib proper.....do.... | $3\frac{1}{16}$ | $3\frac{1}{16}$ |
| Diameter of squib proper.....do.... | $\frac{1}{128}$ | $\frac{1}{128}$ |
| Weight of powder in squibs (average of 10).....grams.. | .40 | .42 |
| Weight of paper in squibs (average of 10).....do.... | .19 | .19 |
| Weight of sulphur in squibs (average of 10).....do.... | ..... | .07 |
| Total weight of squibs (average of 10).....do.... | .59 | .68 |

Screening tests were made by using screens of 20, 40, 60, 80, and 150 mesh, respectively, with the following results:

*Screening tests of combined powder from 10 squibs.*

| Designation of sample. | G. | | H. | |
|---|---|---|---|---|
| | *Grams.* | *Per ct.* | *Grams.* | *Per ct.* |
| Caught on 20-mesh screen | 0.0 | 0 | 0.0 | 0 |
| Caught on 40-mesh screen | 2.97 | 73 | 3.02 | 72 |
| Caught on 60-mesh screen | 1.00 | 25 | 1.11 | 26 |
| Caught on 80-mesh screen | .03 | 1 | .03 | 1 |
| Caught on 150-nesh screen | .02 | 1 | .04 | 1 |

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The time of burning of the match of each squib was determined, care being taken that the match was neither untwisted nor twisted tighter. Ten squibs were tested with the following results:

*Length of time match of squibs burned.*

| Designation of sample. | G. | H. |
|---|---|---|
| | *Seconds.* | *Seconds.* |
| 1 | 48 | 36 |
| 2 | 46 | 37 |
| 3 | 51 | 42 |
| 4 | 59 | 35 |
| 5 | 63 | 33 |
| 6 | 75 | 30 |
| 7 | 86 | 25 |
| 8 | 50 | 28 |
| 9 | 52 | 36 |
| 10 | 42 | 36 |
| Average time of burning | 57 | 34 |
| Minimum time of burning | 42 | 25 |

Tests were made with the two samples of squibs in gallery No. 3, previously described, by igniting the match of the squib and then inserting the squib, match end foremost, in the gallery.

In 10 trials with sample G the match burned without igniting the 8 per cent gas mixture, but in every case spitting of the squib ignited the mixture.

Similar trials were made with sample H and the match of the squib ignited the 8 per cent gas mixture in every one of the 10 trials.

As a squib must be propelled from the mouth of a hole to its heel by the force of the spit developed by the burning powder train, it seems quite impracticable to adequately protect this spit from inflammable gas mixtures within mines. Hence the use of squibs of any kind in mines generating inflammable gases should be condemned.

## PUBLICATIONS RELATING TO MINE ACCIDENTS AND TESTS OF EXPLOSIVES.

The following publications, except those having a price affixed, can be obtained free by applying to the Director of the Bureau of Mines, Washington, D. C. The priced publications can be purchased from the Superintendent of Documents, Government Printing Office, Washington, D. C.

### PUBLICATIONS OF THE BUREAU OF MINES.

BULLETIN 17. A primer on explosives for coal miners, by C. E. Munroe and Clarence Hall. 61 pp. Reprint of United States Geological Survey Bulletin 423.

BULLETIN 20. The explosibility of coal dust, by G. S. Rice, with chapters by J. C. W. Frazer, Axel Larsen, Frank Haas, and Carl Scholz. 180 pp. 14 pls. Reprint of United States Geological Survey Bulletin 425.

BULLETIN 26. Notes on explosive mine gases and dusts, with special reference to explosions in the Monongah, Darr, and Naomi coal mines, by R. T. Chamberlain. 1909. 67 pp. Reprint of United States Geological Survey Bulletin 383.

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TECHNICAL PAPER 4. The electrical section of the Bureau of Mines: its purpose and equipment, by H. H. Clark. 1911. 12 pp.

TECHNICAL PAPER 6. The rate of burning of fuse as influenced by temperature and pressure, by W. O. Snelling. 1911. 28 pp.

MINERS' CIRCULAR 2. Permissible explosives tested prior to January 1, 1911, and precautions to be observed in their use, by Clarence Hall. 1911. 12 pp.

MINERS' CIRCULAR 3. Coal-dust explosions, by G. S. Rice. 1911. 23 pp.

MINERS' CIRCULAR 4. The use and care of mine-rescue breathing apparatus, by J. W. Paul. 1911. 23 pp.

MINERS' CIRCULAR 5. Electrical accidents in mines: their causes and prevention, by H. H. Clark. 1911. 10 pp., 3 pls.

## PUBLICATIONS OF THE UNITED STATES GEOLOGICAL SURVEY.

[Transferred to the Bureau of Mines.]

BULLETIN 333. Coal-mine accidents: their causes and prevention; a preliminary statistical report, by Clarence Hall and W. O. Snelling, with introduction by J. A. Holmes. 1907. 21 pp. 5c.

BULLETIN 369. Prevention of mine explosions, report and recommendations, by Victor Watteyne, Carl Meissner, and Arthur Desborough. 1908. 11 pp. 5c.



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